# COLYER'S MANAGEMENT OF STEAM BOILERS & ENGINES

# TREATISE

ON THE

# WORKING AND MANAGEMENT

OF

# STEAM BOILERS AND ENGINES.

BY

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# PREFACE.

I HAVE been induced to write this work for the purpose of providing a small treatise giving an outline of the principal kinds of engines and boilers in general use, to indicate the most suitable forms for particular purposes, and to give simple rules as to their working and management. I do not think that any work has yet been written that is of much service to the proprietors and users of steam engines and boilers, for whom this work is specially intended. The design of the book is to convey leading instructions and simple rules as to the working and management of steam boilers and engines, in a form easy to understand; it is hoped that the work may be acceptable to those for whom it is principally intended, as well as for any one who takes an interest in such matters.

The large number of engines and boilers in use in this country, and the small knowledge possessed by

many proprietors of such apparatus as to the proper and economical way to work them, will be, I hope, a sufficient apology for trying to supply a want many have expressed for a book of this kind.

With all its faults and shortcomings, I leave it to the lenient consideration of my readers.

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# CONTENTS.

ON THE

# WORKING AND MANAGEMENT

OF

# STEAM BOILERS AND ENGINES.

## CHAPTER I.

### INTRODUCTION.

THE proper and economical working and management of steam boilers and engines is a subject worthy of careful consideration; the various mills and manufactories in the country usually derive the motive power for their machines from this apparatus. The object of this work is to give an idea to managers and proprietors of such places, as to the most suitable kind of engine and boiler for their purposes; and to supply them with suggestions as to the best system of management. The economical working of boilers and engines is a matter of great importance, especially in large

concerns; the subject does not hitherto appear to have had the attention it deserves. The selection of the best kind of engine suitable for a mill or manufactory, is often a matter of some difficulty, to meet this want a general outline of each class in general use is given, to help the purchaser to form a right judgment in the matter. It is not intended to enter into much detail as to the construction of boilers and engines, it being assumed that most people who read the book are fairly conversant with such matters. In many factories a large loss annually takes place from the careless management of the motive power; it too often happens that the working is left in the hands of ignorant men, with the result of great waste in fuel, and too often in the occurrence of serious accidents. The author ventures to recommend all users and proprietors of steam boilers and engines, to make themselves acquainted with the construction and working of the machines by which motive power is given to their mills, and also that they should use more care in the selection of men to whom is intrusted apparatus so fraught with danger and possible heavy loss, when not skilfully managed; added to which a careless stoker especially will cause heavy loss in the extra quantity of coals used beyond

the amount really required when the boilers are properly worked. The first subject treated will be "Boilers, their Fittings and Appliances," with proposals for their proper working and economical management. An outline of the different classes of boilers is given, also an idea of the most suitable kinds adapted for particular purposes. Engines are then treated, a short description of the forms or classes generally used is given, and rules for working, speed, and consumption of steam, &c. Boiler and engine house construction is also treated, together with boiler (brickwork) settings, and the foundations for engines. Technicalities have been avoided as much as possible, in order to make the work more useful to those who are not engineers by training, and to express, in plain language, rules and ideas for their guidance. The subject of engines and boilers is too large to treat in detail here; any one wanting any further information is referred to the author's book upon 'Steam Engines and Boilers' (E. & F. N. Spon, London), in which will be found details of construction of all descriptions, both for land, locomotive, and marine purposes.

## CHAPTER II.

### BOILERS.

THERE are two principal classes of boilers in general use for land engines, viz. "vertical" and "horizontal"; the former are usually of the tubular kind, the latter are made in several forms, viz. "Cylindrical," "Cornish," "Lancashire," "Multitubular," and "Return flue boilers." A short description of each kind will be given to enable the reader to form an idea of the respective merits of each class and their adaptability for particular kinds of work and under special circumstances. It will also enable the reader to understand more clearly the rules laid down for working, &c. The Cylindrical, Cornish, and Lancashire kinds require setting in brickwork; the others do not require any setting; there are many cases where a brickwork setting could not be used, partly on account of the limited space at command, and also in places where the extra dead weight could not be permitted. Multitubular boilers on the locomotive plan are the most suitable in such a case; the

boiler rests upon iron cradles, the exterior being covered with felt or non-conducting composition. The various kinds of boilers will now be described.

## Vertical Boilers.

Vertical boilers may be divided into three principal kinds—Cross-tube, Multitubular, and Field's patent tube: each of these will generate steam rapidly. These boilers are suitable for use where the floor space is very limited, and also in cases where temporary steam power is required; they can be delivered to their position almost ready for use, and simply require a stone bedded on concrete to stand on. In some instances the boilers are fixed upon an iron frame or truck on wheels, and can be run on to the required spot at short notice.

*The Cross-tube* kind are suitable for rough work, especially where unskilled labour is employed to work them, they do not require so much attention from the stoker, and are not so liable to leak as the others. In this kind of boiler there is an internal fire-box of the usual description, and on the top of this is riveted an internal tube, with several cross tubes passing through it; the water in the

boiler passes through these tubes, and by this means steam is generated quickly. These boilers are specially suitable for portable steam cranes, pile-driving machines, mortar mills, and other out-door work.

*The Multitubular kind* are made in much the same manner as a locomotive boiler, with an internal fire-box and tube plate near the top, a large number of small tubes are riveted to the top of the fire-box at one end, and to the tube plate which forms the bottom of the smoke-box at the top of the boiler. The heat from the fire passes through these small tubes, which present a large heating surface to the water in the boiler surrounding the tubes, thus causing rapid circulation and generation of steam. The steam space in these boilers is of necessity rather small, and priming sometimes takes place unless the boiler has careful attention. Priming is sometimes caused by using dirty water, or by the presence of grease or tallow in it.

*Field's Tube Boilers* are made with a fire-box as before, the top plate is drilled with a number of holes about 2 inches in diameter, and in these holes are suspended short tubes closed at the lower ends and open at the top ends which are in communication

with the water in the boiler; in these tubes internal tubes are placed, they are open at both ends, and at the top are funnel shape and have wings to suspend them; the cold water passes into the external tubes, and when heated it passes up the centre tubes; very rapid circulation is thus produced. Boilers of this kind are much used for steam fire-engines, and in cases where steam has to be generated rapidly. They are not so suitable for chalky water, and where there is much silty deposit of any kind.

All the above boilers have the smoke-shaft attached directly to the top of the smoke-box; it is usually made 9 or 10 inches in diameter, of wrought iron, in about 8 feet lengths, each length being flanged to admit of making it of sufficient height to obtain the requisite draught. The draught of the boiler is sometimes increased by carrying the exhaust pipe from the engine into it; this however is only useful in short funnels.

The boilers should be covered with non-conducting composition; in some cases the composition is covered with either wood or sheet-iron lagging, secured by wrought-iron hoops or bands.

## Horizontal Boilers.

*Cylindrical.*—These are a very useful kind of boiler, they are made with a cylindrical shell or casing, and have the ends riveted on, these are either made cup-shape or hemispherical. The shells are made in as large plates as possible, and each of the ends in one piece, solid flanged, a steam chest is riveted to the top of the boiler; manhole and mudhole doors are also provided. The fire is placed *under* the shell. The seam plates or laps of the boiler must be placed *away* from the front of the furnace, to prevent the flames injuring the joints, it is the custom to make the front plate over the fire of sufficient length to go *over* the bridge of the furnace. The area of the furnace bars for this kind of boiler must not be less than 1 square foot per horse-power, and in cases where much refuse is required to be burned it must be made larger.

*The fittings of the boiler* should be, two glass water-gauges, to show the height of the water in the boiler; the reason for fixing two of these water-gauges is to ensure that the true water-level is shown, in case the passages of one set should get stopped from any cause. Two gauge-cocks should be provided, one being fixed at the steam space and one at the water-

level. A safety valve should be fixed on the top of the steam chest, for the purpose of giving relief to the steam in the boiler, when it rises above the maximum working pressure. A steam shut-off valve should also be fixed on the steam chest, to regulate the supply of steam from the boiler and to shut it off when required. A feed-valve and supply pipe should be attached at the front of the boiler, for the purpose of supplying the feed-water. A blow-off cock should be fixed at the bottom of the boiler at the front, to blow out the steam and water at intervals and when it is thrown out of action. A float and alarm whistle should be placed on top of the shell to indicate the level of water inside the boiler, and to give an alarm in case it falls too low. A steam gauge must be fixed at the front of the boiler, to show the internal pressure. An injector should be fixed at the front for supplying the feed-water, and a tank placed on top of the brickwork setting to supply same, this tank is fitted with a self-acting ball-valve, it should *always* be placed *above* the injector, in most instances it is preferable to have a direct-acting steam feed-pump, they are very useful machines, and not very liable to get out of order, the amount of steam used by the best kinds is small.

*Cornish Boilers* are constructed with an outer shell and an internal tube passing through the whole length of the boiler, the end plates are flat, and are attached to the shell and tube by L-iron rings, or they may be solid flanged and riveted direct to the shell plates; the tubes should be strengthened on the exterior at intervals with L-iron rings. The furnace is placed within the tube at the front end, the flame passing from the fire over the bridge at the end of the fire-bars, through the tube, and so out to the side flues; the furnace bars are made in two lengths, supported on wrought-iron bars bolted to the internal tube of the boiler, a fire-door is fixed to the front plate. A steam chest is provided on top of the boiler as before, the hole in the shell at this place need not exceed 6 inches to 8 inches diameter; this is sufficient for steam to pass through, and prevents the shell plates at this part from being weakened by cutting a larger hole. The manhole should be placed at the back of the steam chest and near the end of the boiler; a ring should be riveted round the opening to give it strength, except in cases where a cast-iron frame is riveted on to the shell, as this answers the same purpose. This is much the best plan, as the joint of the manhole cover is planed, it can easily be

taken off and re-jointed without risk of leakage. The steam pipes and connections of all kinds should be attached to cast-iron seats riveted to the boiler. These joints should be faced and the holes drilled; this allows the pipes to be easily and quickly removed in cases of emergency and prevents injury to the plates of the boiler by leakage at the various points of attachment.

The fittings for a boiler of this kind will be the same as before described (p. 8); the sizes will of course depend upon the power of the boiler.

This kind of boiler is not usually made in larger sizes than 6 feet diameter, where larger power than this is required Lancashire or two-tube boilers should be used. The front of the boiler should have gusset stays, to connect the end plates with the shell.

These boilers are a very favourite type, they are economical in working, and quite safe with an ordinarily intelligent stoker. They require setting in brickwork; this is described at p. 19. This work should always be done by specially skilled people, as upon the proper setting will much depend the economical working of the boiler.

*Lancashire Boilers.*—These boilers are made in the same way as the above, except that they have *two*

internal tubes, the end plates are flat and attached to the shell and tubes in the same manner as before. A furnace is placed in *each* tube, and a furnace door, fixed to the front plate, is provided to each. These boilers are used when the diameters exceed 5 feet 9 inches to 6 feet.

The fittings and furnaces do not differ from those described for Cornish boilers. The diameter of these boilers should not exceed 7 feet 6 inches to 8 feet, and the length about four to five times the diameter. The area of the fire-grate should be $\frac{3}{4}$ to 1 square foot per horse-power, and the length of the bars, if it can be avoided, should not be more than 6 feet. The seams of the shells should be double riveted, the front and end plates should each have four diagonal braces or gussets, to connect them with the shell and tubes, the internal tubes have rings at intervals riveted to the exterior, and all the laps, seams, or joints placed *away* from the furnace. The boiler should be set to drain at the front end at the blow-off cock, and be provided with proper mudhole doors for cleaning out. The steam chest is the same as for Cornish boilers, these boilers are most economical in action. The furnaces, especially as to the air spaces, must be adapted to the particular kind of fuel to be used.

When two or more boilers are used, they should be connected together by a steam pipe, a shut-off valve being provided on the steam chest of each boiler, and also on the main pipe between each set or sets of boilers, to enable the steam to be shut off from any part if required. An expansion joint should be placed in the pipe between each boiler, to allow expansion in the boilers and pipes to take place, without doing injury to the joints of the valves and pipe connections.

*Multitubular Boilers.*—These are made upon the locomotive plan, with an external shell and an internal fire-box or tube at the front end. The tube is closed by a plate at the end of the furnace, and in this plate a number of small tubes 1½ inch to 2 inches diameter pass through and are riveted; at the other end of the boiler another plate is riveted to the shell, and through this plate the back ends of the tubes pass and are riveted. The shell plates of the boiler are continued beyond this end tube plate, forming the smoke-box, the end being closed by a plate which is provided with a door to enable the tubes to be cleaned out. The furnace bars are placed in the tube at the front of the boiler; the flame passes over the bridge through the small

tubes to the smoke-box, the water surrounds these tubes, and by the large heating surface they present, steam is rapidly generated. The flues to the shaft are usually constructed of plate iron, and may be carried some distance without injury to the draught. The fittings for the boilers do not differ from those before described.

The exterior of the boilers should be protected by felt and lagged with wood or sheet iron secured by wrought-iron bands, or they may be covered with non-conducting composition as before described.

Boilers of this class are very suitable where steam power is required on a quay or jetty, or when placed in vaults or on the upper floors of a building, they do not require any brickwork setting, they are very economical as to the consumption of fuel, generate steam quickly, and will last for many years when used with ordinary care. They simply require to rest in two cast-iron cradles, these may either be placed direct on a stone floor or on timbers, in both cases a good sound bed under the stone, &c., must be obtained.

Boilers of this class may also be used for temporary purposes, they are quickly set to work, and not requiring any foundation, can be also easily and rapidly removed when done with, in cases of

this kind the smoke-funnel may be fixed direct to the top of the smoke-box; the pipes forming the funnel or shaft should not be in more than 8 feet to 9 feet lengths, they should have faced flange joints and be bolted together.

*Return Flue Boilers.*—These boilers are not much used; they are constructed on much the same plan as a Marine boiler. The manufacturers claim for them some advantages, such as saving in room and increase in the heating surface, in ordinary cases their use cannot be recommended. The fire in these boilers is placed under the shells, the heated air and flame passes to the back of the boiler, thence by an uptake through small tubes to the front of the boiler, thence to the side flues in brickwork, and out to the main flue to the shaft. The doors for cleaning the tubes in this case are placed at the front of the boiler. In some instances a long cylindrical steam chest is attached to the top of the shell of the boiler by two saddle pipes; in other cases vertical steam chests of the ordinary kind are used. The smoke-funnel may be attached direct to the top of the smoke-box if desired; this, however, somewhat affects the economy of working as to the fuel, as some of the heating power is lost. In some cases the internal

tubes give trouble and leak: this may possibly be due to the fact that the shell is held in the brickwork, and cannot readily expand and contract.

There are several other kinds of boilers in occasional use; as, however, there are very few cases where one of those above described cannot be employed, it has not been thought necessary to describe them in detail. The general proportions of the various boilers are not treated here, as it would be beyond the scope of the present work; any one requiring any further detailed information as to this is referred to the author's book upon 'Steam Engines and Boilers' (E. & F. N. Spon).

Too much stress cannot be laid upon the importance of the proper proportions and careful manufacture of boilers and their fittings; only manufacturers of the highest reputation should be entrusted with such work. It must be borne in mind that cheap and inferior work may not only prove a source of danger, but will be the dearer in the end, from the constant loss occasioned by the extra consumption of fuel that may be necessary to generate the steam, and the frequent repairs that may also be necessary on account of faulty work. Proprietors and users of boilers will best consult their own interests by

careful attention to the above. From an experience of many years, the author has found that several large and well-known makers of boilers have never had an accident of a serious nature occur to their boilers, unless caused by the culpable neglect of incompetent men. He also believes that the accidents and explosions that only too often occur to boilers, would be almost entirely prevented by only employing firms of the highest reputation, as recommended above.

## CHAPTER III.

### BRICKWORK SETTINGS FOR BOILERS.

CYLINDRICAL, Cornish, and Lancashire boilers, also Return flue boilers require setting in brickwork. In the preparation of the bottom much care should be used to obtain a solid and dry foundation; an excavation should be made until a good sound bottom is found, on this should be laid a bed of concrete from 12 inches to 24 inches thick; the thickness of this will of course depend upon the nature of the bottom. The brickwork foundation should be carried over the entire surface of the concrete, with proper footings about four courses or 12 inches deep. The bottom of the flues for Cornish boilers should be kept as near the floor-line as possible, and means taken to insure their being kept dry and free from damp and water, the side flues should be of sufficient size to permit of periodical examination; for this purpose, at the front of the flues cast-iron doors and frames set in the brickwork should be provided, flue brushes should be passed through

these doors to sweep out the flues, and lads should be sent in at certain periods to sweep and clean them thoroughly, the exterior of the shell plates of the boilers should also be cleansed and kept free from soot and dirt.

The souffite of the brickwork side flues should be 6 inches below the top of the internal tubes in the boiler in the case of Cornish and Lancashire boilers, and 6 inches below the water-line in Cylindrical boilers. Boilers should never be set with a centre feather or wall, it is a dangerous plan, as in the case of any leakage occurring, the plates are sure to get corroded, and being covered by the brickwork, such defects cannot readily be discovered when the men are examining the interior of the flues and outer shell of the boiler. Another very grave objection to the centre wall is that the plates, owing to the dead weight of the boiler resting at this point, are liable to become flattened and strained; this action constantly going on leads to permanent injury to the seams or joints of the shell, thus causing leakages and corrosion which is a very fruitful source of danger; a leaky seam at one end of the boiler may cause injury for some distance on the bottom plates.

The best plan to set boilers is on two side

fire lumps or walls, with side flues and a split draught into a bottom flue; all the flues should be lined with fire-bricks 4½ inches thick. The exterior brickwork outside the flues should not be less than 14 inches or 1½ brick, the front of the boiler should be built in blue (or black) bricks, the side walls should be carried about 14 inches above the top of the flues, and the brickwork covered with 3-inch York stone paving. The damper should work in a cast-iron slide and frame, and be connected to a chain passing over pulleys to the front of the boiler, a counter-balance weight placed in a convenient position is attached at this end of the chain. At the front of the brickwork setting a cast or wrought iron foot-plate about 4 feet wide should be provided, and an open brickwork channel formed under the same for the blow-off and other pipes to pass through. A cast-iron door and frame should be provided at the blow-off cock, the plug of the cock should stand up, and be worked with a box spanner. The boiler setting should stand quite independent of the walls of the house; a space of at least 3 inches should be left between them to permit of expansion of the brickwork setting without doing any injury to the side walls.

*Setting of Return Flue Boilers.*—This is on much the same plan as those described above, the fire is usually placed under the shell; the flame passes into a lower flue beyond the bridge to the end of the boiler, it then passes through the small internal tubes inside the shell to the front smoke-box; the draught is then split, and the heat passes into side flues to the shaft; the action may be reversed, or the side flues may be dispensed with. As before stated, this sort of boiler is seldom used, though there may be some circumstances where it may be desirable. In some cases these boilers are not set in brickwork, and are used like a marine boiler, the heated air only passing through the internal tubes to the smoke-box in the front of the boiler, and thence to the chimney, the boilers when not set in brickwork are covered with non-conducting composition, and are sometimes lagged on the outside with wood staves, secured by iron bands.

## Boiler Chimney.

The *Chimney* need not be placed close to the boiler, the flues leading to it must be kept dry and air-tight; the height of the chimney or shaft and the area at the top will depend upon the number and size of the boilers, and on other circumstances,

a soot-door should be provided at the bottom of the shaft, to clean out when required. Several boilers may be taken into one shaft without any detriment to the draught, the shut-off dampers in the main flue must be closely fitted in this case.

The interior of the flues and also the shaft for at least 15 feet high, should be lined with fire-bricks, these bricks must *not* be bonded into the shaft, but left clear of it. The main flues, wherever possible, should be kept *above* the floor-line, in order to avoid any water or damp, the size of the flue will depend upon the number of boilers, provision must be made for readily cleansing the flues, and also the bottom of the shaft.

For small boilers the shaft may sometimes be constructed of boiler-plate iron, it should be stayed by three tie-rods attached to a band near the top, and to any suitable place near the bottom, in case of heavy winds, this will keep the shaft in proper position, a soot-door should be provided at the bottom to give access for cleaning. The thickness of the plates should be $\frac{3}{16}$ to $\frac{1}{4}$, and either lap or butt joints, in most cases the tube should be flanged, jointed at every 8 feet or 9 feet, and bolted together, the joints must be made perfectly tight, to prevent any leakage of air into the shaft at the side.

## CHAPTER IV.

### BOILER HOUSES AND WORKING OF BOILERS.

*Boiler Houses* should be of fair dimensions; the height should be about 12 feet to 14 feet from the floor-line to the wall-plate, the thickness of walls may be 14 inches. Ample ventilation should be provided, but strong draughts of air at the boiler front should be prevented wherever possible, no part of the boiler should be exposed to the weather; it is an error to leave the front or any part of the house open, not only is much loss of fuel caused by this, but injury is also done to the boiler plates by streams of cold air passing into the furnaces. Good light should be provided, and the windows made to swing; in large houses a lantern light may be constructed in the roof, part of the sashes in this case should be hung on pivots and be opened by simultaneous opening gear, worked from the floor of the house. The roof framing may be wood or iron, covered with slates laid on close boarding. The paving or floor of the house may

either be York stone or Stuart's patent granolithic pavement. Iron plates about 4 feet wide must be laid down in the front of the boilers, to allow the fires to be drawn without doing any injury to the floor, stone, as a rule, will crack when heated coals or ashes are drawn out, and especially when quenched by water.

*A Coal Bunker* should be provided to contain the fuel, this may be made of wrought-iron plates with sliding doors at the bottom to take out the coals as required. In some cases coal-trucks holding about 10 cwt., running on wheels, are found convenient; they are provided with a shoot at the end or sides, this is fitted with a sliding door. When there is space outside the house, the coal bunker may be constructed in brickwork, with a hole or holes in the wall, fitted with sliding doors, a large stock of coals may by this means be stored, and all inconvenience from dirt in the house avoided when delivering the coals.

The space in front of the boiler for stoking should be 8 feet in the clear. The feed apparatus *should be placed in the boiler house*, to prevent the stoker leaving the house especially in cases of emergency, when necessary to start the pump, on

account of the level of the water in the boiler being too low. Whenever possible, the boiler house should be separated from the engine house, but a door of communication may be made between the two houses, this must not, however, be done in the case of Gasworks, as the engine room contains the gas exhausters, and, in case of any leakage, the furnaces of the boilers might cause an explosion of gas.

The boiler house should be supplied with the following fittings:—

A set of spanners to take all the nuts; these should be placed on a rack on a board which should be fixed to the walls of the house, box spanners should also be provided; these should be made with T heads. A complete set or sets of stoking tools, viz. two shovels, a rake, a slice, and a pricker, also a water hose, fitted with a union and cock, for quenching the fire when necessary.

## Working of Boilers.

The management and working of steam boilers, and the rules to be observed to prevent accidents, are a most important consideration; the want of a proper knowledge of such matters has too often led, as before stated, to serious accidents, causing loss of life, much suffering, and heavy losses to the pro-

prietors; the following rules are given, the observance of which will save proprietors of boilers much trouble, anxiety, and loss.

No men should be employed to look after a boiler unless they have been properly instructed, and possess the requisite knowledge, it too often happens that a boiler is placed in the hands of men who are quite unfitted for the work; it may then become a very dangerous apparatus. It is to be hoped the Legislature will some day make it obligatory on all boiler users and owners to employ only properly qualified men for the purpose, and that boilers will be worked under State or municipal supervision; the author believes if this plan is carried out, accidents of a serious nature will be of rare occurrence, if not altogether prevented.

Having in former chapters given an outline of the general construction of boilers and the manner of setting them, the next important consideration is the water supply, and the fuel to be used, the best plan of stoking and the management of the fires is also very important, these matters will now be treated.

*Water Supply.*—Water for boilers should be obtained as pure as possible; river water, when clean and free from silty deposit, is very suitable, a hard

water, especially from the chalk, is as a rule, the most unsuitable, water containing sulphur or ammonia, or any tarry matter, should never be used. A cast-iron tank containing sufficient for at least two days' supply should be provided, and fixed at a sufficient height to command the top of the boilers; this tank wherever possible should be placed under cover. Where the local water is very hard, it may be worth attention to soften it by the Porter-Clark process; in the case of several boilers this will pay, as much corrosion is prevented, and the boilers do not require cleaning out so often, added to which the wear of the plates is much lessened.

The feed-water should be regularly supplied to the boiler; the water must not be allowed to fall to the minimum or *danger* level, if the water is supplied by Injectors, care should be taken to see that they are in proper working order. This apparatus has been so much improved in late years, and is so simple to work, that with the most ordinary attention it is not liable to get out of order, a small feed-tank, from which the water supply is taken, should be placed on the top of the brickwork of the boiler, the main tank of the place feeds this by means of a self-acting ball-valve; care should be taken to keep the tank covered, and the water

perfectly clean. The overflow from the injector should always deliver into an *open* funnel; if this is carefully watched when using the injector, no error or accident can take place. The feed-water should pass into the boiler at about the water level by means of a perforated tube running the whole length of the boiler, the feed-valve should be placed on the front of the boiler, convenient to the man's hand; the valve should not be attached to the screw spindle, but be free to rise and fall in its seat, so as to prevent any of the water from the boiler running back to the pump in case of any break or stoppage in the pump or the pipes, in some cases a back-pressure valve is also added to act in case the valves stick.

*Feed-pumps.*—When water is supplied by a force-pump, the valves must be carefully looked to, pet-cocks are fitted to the pumps, by the opening of which the stoker can tell if the pump is working properly. When the pet-cock is opened, if no water passes through it, the valves may be stuck, in this case the stoker must try and release them by giving the valve chamber a smart tap with a hammer or mallet, the valves should then drop into their seats; in case they do not at once do so, then take off the bonnets of the valve-box and lift out the valves; a

stick or some dirt may be the cause of the obstruction, and can thus be easily removed. If the level of the water in the boiler is low at such a time, the generation of steam must be stopped, the damper closed, and the fire-door opened.

Should no defect be found at the valves, examine the plunger of the pump, to see if it is drawing air at the gland, and if so the gland must be screwed up to compress the packing.

A back-pressure valve, as before named, is usually fitted in the delivery pipe to the boiler, the pipes should be carefully examined at intervals, to make sure no deposit has taken place in the inside, and the passage of water thus obstructed; this more particularly applies in cases where the water contains lime or other calcareous deposit.

It is always advisable to have the feed apparatus in *duplicate* in every boiler house—either two injectors, or one injector and one feed-pump. Both the injector and the feed-pump should be of ample size, according to the power of the boiler.

*Steam Pumps.*—Since the introduction of direct-acting steam pumps, some years ago, they have been so much improved, and are now so moderate in price, that no boiler house should be without them,

one advantage in favour of the steam pump is, that it will draw water at about 25 feet below the suction valve, and at a *higher temperature* than is possible with the injector, the pressure of steam required to work the pump is not more than 15 lbs. per square inch, the author has used steam as low as 10 lbs. per square inch. The pumps can be worked from a few strokes per minute to 50 or 60 strokes per minute; a higher speed than this is not advisable, although in some instances it may be unavoidable, a certain amount of slip or loss of water through the valves must be allowed in this case.

*Water Heater.*—The feed-water should be passed through this apparatus, it consists of a cylinder having a number of small tubes inside it, the exhaust steam from the engine passes through these internal tubes, and thus heats the water in the cylinder. Water may be used with the pumps at 120° of heat, and at even a higher temperature; but with the "Injector" it should not be more than 100° to 110°.

*The Level of the Water in the Boiler* must never in any case be less than 6 inches *above* the internal flues or tubes in the case of Cornish or Lancashire boilers, and in the case of cylindrical boilers not less than 6 inches above the top of the side brickwork flues, the water-line in Multitubular boilers should not be

lower at any time than 6 inches to 7 inches above the top of the internal tubes.

*The Glass Water-Gauges* should be opened at frequent intervals to ascertain the level of water inside the boiler; the glass tubes should be opaque at the back, and be kept perfectly clean; the size of the cocks and tubes should be ample, the cocks should be the packed gland kind. As a rule, two of these water-gauges should be fitted to a boiler, in case of the glass tube breaking or stopping up in one, the other one is available, and will always indicate truly the actual level of the water inside the boiler, after one of the cocks of one set of gauges has been opened, try the other one, to make sure the level of the water which is indicated is the true one.

*The Gauge-Cocks* should also be opened frequently; the upper cock should show *steam*, and the lower cock *water*; *if water does not come out of this lower cock when opened*, there is danger, the water is too low, and an accident will take place if proper means are not taken to avoid it. In such a case, look immediately to the pump and injector if at work, and learn the cause of their not acting, should no water show in the glass or at the lower gauge-cock, immediately close the damper and open the fire door; *do not in any case put on the pump or the injector*,

the blow-off cock may be opened and the fire drawn. Under all ordinary circumstances, when these rules are attended to, no accident will take place, such a state of affairs cannot at any rate arise unless there has been great neglect on the part of the stoker. The man in charge should carefully watch the level of the water in the boiler, and attend to any defect before the danger point above indicated is arrived at, as this is a most important matter, too great stress cannot be laid upon the necessity of diligent and intelligent care upon the part of the attendant, especially in all matters relating to the feed-water supply.

*Fuel and Stoking.*—The next most essential matter in connection with the working of boilers is the supply of fuel, and the manner of keeping up the fires, the best kind of fuel is clean screened small coal about the size of a pigeon's egg, usually called "nuts," "slack" or coal dust is not economical to use, partly because it is mixed with rubbish, and also from the tendency to flare and consequent loss of heat up the chimney,—added to this, much more smoke is caused, which is a serious thing, especially in the London district, where the Smoke Act is in operation.

In getting up steam in the morning, the coal that

has been banked up on the dead-plate the night before should be pushed forward and spread in a thin layer on the bars, and a small quantity of fresh coal placed on the top, as the fire gets hot, more fresh coal should be placed on the dead-plate, and gradually pushed into the furnace; by this means the green coal will be coked before it gets to the bridge at the back of the furnace. When the fire is made up, the red coals should be pushed to the back part of the bars, and fresh coal put on the dead-plate. When boiler fires are supplied with coal in this way, no smoke should be made, it should be borne in mind, the object is to *prevent* smoke, *not to attempt to consume it* after it is made. If the furnace is fitted with rocking bars, they should be worked once or twice per hour to break up the clinkers, and to mix up the fire.

Coke may be used as fuel, but it is not as a rule so economical as coals, the two kinds of fuel should *never* be used together. Coals should be wetted before use, a water pipe and hose in the boiler house is very convenient for this purpose, it can also be used for quenching the fires when drawn. Good Newcastle coal is about the best to use in London, in country districts the nearest coal available must of necessity be used; it is not economical in any

case to use very large coal; when too large, it should always be broken into moderate sized pieces, this is essential for even and steady firing.

The air space through the fire-bars must be of sufficient area to suit the particular kind of coal, the hard and common kinds require a larger supply of air, the bars in all cases should be made rather narrow, and the air spaces close together; they are made in two lengths, and, as a rule, the total length of the furnace bars must be not more than 6 feet from the dead-plate to the bridge. Room must be left at each end of the bars to allow them to expand as they get heated, room for expansion must also be left across the bars. The fuel should be supplied not only *regularly* but *evenly*; the thinner the fire is the better. Keep the thickness of the fire at all times as equal as possible, and free from holes or bare spaces upon the bars; by opening the fire-doors at intervals this defect can be seen, and should be at once remedied.

*Smoke Furnaces.*—There are many appliances for the prevention of smoke in boiler furnaces; some are very effective in action; the object sought to be obtained in all is—the slow, regular, and perfect combustion of the coals; by this means all the gases are burned in the furnace before the coal reaches

the bridge; heated vapour in this case only passes to the flues, and by this means smoking at the top of the shaft is prevented.

It is needless here to describe any of the numerous apparatus for this purpose, it may, however, be noted that the most successful kinds for hand-power or automatic working are: Wright's, Clarke's, and Martin's; and those driven by power: Juckes' Vickers', and Smith's, those driven by steam power as a rule are only suitable for large boilers; they all effect much saving in coals, the commoner kinds of coals generating steam as well as the best kinds; a large saving in cost is thus effected. Furnaces of this kind of necessity require very careful attention, like most other things, they fail with careless and incompetent men.

Welsh coal is sometimes used, they are almost smokeless, but are more expensive than other kinds; in some districts the high price on account of the rates of carriage, entirely prohibits their use.

Finally, it must be remembered that a careless, ignorant, and incompetent stoker can increase the consumption of coals 30 to 40 per cent. by bad firing. No smoke should be emitted from the chimney when the stoking is performed in a careful and proper manner.

## CHAPTER V.

### FITTINGS OF BOILERS AND METHOD OF WORKING.

ALL well-made boilers are supplied with fittings as described at page 8, the most important of which are the safety valves, particular attention is directed to these; a large number of the accidents that occur to boilers have been traced to indifferent safety valves, or the neglect and careless use of them. The valves should be weighted to the maximum working pressure when the weight is in the end notch of the lever, and the lever should be graduated at spaces to give 10 lbs. per sq. in. variation, *under no circumstances should the valves be overweighted.* The valves should be kept clean; if possible, they should be taken out of their seats once per week and cleaned, making sure that all corrosion and dirt is removed; the pins and joints of the lever, &c., must also be examined to ensure their working easily. If ordinary care is taken, no danger from over-pressure in the boiler can arise. The safety valves should always be made double, that is, two valves and seats fitted to one pedestal, to ensure that one will act, should

the other stick from any cause, the valves should have very free area. The levers should never be lifted by the stoker, *it is attended with danger*, no one coming into the boiler house should on any pretence be allowed to touch the valves or levers. Lock-up safety valves are sometimes provided; they are weighted a little above the maximum working pressure, and will blow off if this is exceeded. A float and alarm whistle may form part of the safety-valve box; the height of the float indicator shows the level of the water inside the boiler, and the whistle gives an alarm when the point of danger is near. Directly the whistle begins to blow, the fire must be slaked, and the damper closed; the feed-water must not be put on if the water level is too near *danger* point.

*The Feed-valve* and its use has been described under feed-water. The glass water-gauges and the gauge-cocks have also been described, the ways or passages of the cocks and pipes must be kept clean and free from deposit or any obstruction, the glasses must be kept perfectly clean and bright, and the cocks clean and tight at the gland packings.

*The Blow-off Valve* should be opened once or twice per day when the water is hard and likely to form

a deposit; it need only be opened for a few seconds each time; this will prevent the scale from settling on the plates, and help to keep the inside of the boiler clean; the pipes leading from the boiler to the blow-off cock, and also the discharge pipes from the same must be kept free from any dirt or deposit. If the blow-off cock is not used at least once per day, it is often found that the dirt and deposit in the boiler settles in the bore of the cock; this must never be permitted. *The Float and Alarm Whistle* must be tested at times to see that it is not sticking, and that it is in good working order; in addition to the float a *Steam Sentinel* is sometimes provided, it is set to blow off about 2 lbs. per square inch above the float whistle.

*The steam valve* at the top of the boiler in connection with the main steam supply pipe should be opened and closed occasionally, to test its condition and to ensure its being in good working order in case of any emergency arising. It may be necessary to suddenly shut off the steam at the boiler, or the connection between any other boiler; this must be done positively, and the valves kept perfectly steam-tight. These valves should be supplied with a large hand-wheel, having a handle in the rim, to

give facility for closing them rapidly if occasion requires; the valve and seat, also the screw spindle and gland, should be made of gun-metal to save corrosion of these parts from the water, the flange joints should be faced in the lathe, and made metal and metal, no sheet-lead or packing material should be used.

*The Feed-pump* must be examined at least once per week, and the packing of the gland and stuffing-box looked to, to see that it is not drawing air. The valves and the interior of the pump should also have careful attention at certain periods, to see that they are in every part free from dirt, or any obstruction. These precautions are specially necessary when the water forms much deposit, and also when the water is from the chalk.

*The Injector* must have very careful attention, and be kept perfectly free from dirt of every description.

*The Feed-water Heater* wants very little attention, it should be cleaned out once in every three months, or oftener if much deposit takes place; by opening the lower cock in the outer casing occasionally much of the deposit will pass out with the water before it has time to settle inside. The top cover,

also the manhole cover of the heater should be taken off about three times per year, to clean the interior and exterior of the tubes and the interior of the casing.

*Blowing off Boilers.*—They should be blown off once per week, and where duplicate boilers are provided they should be turned over once per month. At the time of change the flues and shells of the boilers should be examined and cleaned, and the interior also cleaned out; by attention to this rule the interior of the boilers may be kept free from deposit; scale should never be allowed to form into a hard substance upon the plates of the boiler.

## INCRUSTATION IN BOILERS.

Many materials have been used to prevent this, those of a chemical kind especially when they contain any acid, should never be used, common soda may with advantage be put in at intervals; refined petroleum is sometimes used in small quantities, it is very effective in preventing scale. All oil and grease should be kept out of the interior of the boiler, as they cause priming. When the interior of boilers are coated with scale or deposit the plates next the flues

or fire are liable to be weakened, by the water not being in contact with them. Heated feed-water helps to prevent scale in boilers, as much of the deposit from the water is left in the lower part of the heater, and a much purer water is thus obtained.

It must always be remembered that scale inside a boiler not only very much *increases the consumption of fuel*, but deteriorates the plates and the fittings in a very rapid way. When the only available water for use is very bad, a scum-pipe may be advantageously used, this consists of a perforated cast-iron pipe fixed inside the boiler, having an open trough on the top, it is placed at about the water level; the deposit floats into the trough, and sinks to the bottom of the pipe, cocks are attached at the front of the boiler in connection with the trough, the scale is blown out when the exterior cocks are opened.

The joints of the mudhole and the manhole doors must be examined at frequent intervals, to see that they are perfectly tight, leakage of steam or water at these points may cause corrosion and injury to the plates. The joint of the blow-off cock also wants careful supervision, especially as it is under the floor and not exposed to view. In the case of chalky or hard water this periodical examination of

all joints is specially essential to save injury to the plates of the boiler.

*Proving Boilers.*—As a rule they should not be proved at a higher pressure than 100 lbs. per square inch, this should be done by a hydraulic pump; the pressure should be *gradually* put on, much permanent injury may be done to the plates by *suddenly* applying heavy pressure. The pressure should remain on some time, the valves and all parts being absolutely closed and free from any leakage, all the seams of the shell and plates should be examined, mark any place where leaking takes place, *but on no account should any caulking be done while the hydraulic pressure is on the boiler.*

The testing of boilers should be done in the presence and under the direction of competent people, and after the boilers are in their place periodical tests should be made, and all the parts of the boiler, wherever possible, carefully examined.

*Painting and Cleaning.*—All parts of the boilers exposed should be well cleaned and painted once or twice per year, tar is not a good thing to put on, as there are many ingredients in it that do not suit boiler plates and are liable to do injury. Before

the painting is commenced, be careful to clean away all rust or other deposit on the plates, and at the same time closely examine them to discover if any damage of importance has been done by any corrosion on their surface. This is a most important matter and should have the most particular attention, or injury of a permanent character may take place and may prove a source of danger.

## CHAPTER VI.

### ENGINES.

For mill and manufacturing purposes there are various kinds of engines used, viz.: "Oscillating" (both horizontal and vertical), "Vertical," "Horizontal," "Beam," and "Direct-acting" engines. These are subdivided again into high-pressure or non-condensing, condensing, and compound engines. A slight outline will be given of each of the leading kinds to indicate their suitability for particular purposes, after which the working and management of each kind of engine will be described, and general rules will be given to be observed in engine houses.

*Steam* is conveyed in cast or wrought iron pipes from the boilers to the engines, the pipes may be wrought iron up to 2 inches diameter, above this size they should be made of cast iron with flanged joints, faced in the lathe, and the bolt-holes drilled. The length of each pipe should not exceed 9 feet; they should be covered with non-conducting composition and kept well painted, the flanges and all

joints being left free to enable the attendant to detect any leakages. Connections to the engine of any kind should be made by faced surfaces, and the holes for the bolts drilled. To permit the pipes to expand without injury to the joints, "expansion" joints should be used, the best kind are made in the form of copper discs, sliding joints do not answer, they are liable to get corroded and so may stick and become the same as a solid pipe.

It is very essential to get the steam into the engine as dry as possible, to ensure this, condense boxes should be provided, and draining pipes from the main pipes taken into them. It is advisable, whenever possible, to give the steam pipes *a fall to the boiler;* this allows some of the condense water to drain back into the boiler.

*Super-heaters* are sometimes used to dry the steam before it enters the engine, these are, however, only of use in large engines; there are various forms of these made by different makers, the operation is in all cases a very simple one.

*The working pressure of steam* varies in different places; it is now usual to work at not less than from 30 to 60 lbs. per square inch, 45 to 50 lbs. may be taken as a good average pressure. The size of the steam pipe must be properly proportioned to the

power of engine, a small wrought-iron pipe should be attached to the pipe *above* the starting valve to take away the condensed water. It is most essential that the steam should be admitted as *dry as possible to the cylinder of the engine.* The exhaust steam from the engine should be taken to a feed-water heater in the boiler house, described at page 30. The size of the exhaust pipe should be ample, all sharp bends should be avoided; also any dips in the pipes; a condense pipe should be attached at the outlet from the engine at *the lowest point* of the exhaust pipe to prevent the condense water running back to the engine cylinder. At each end of the cylinder condense cocks with pipes attached should be provided to blow out the water at each side of the piston on starting the engine; all these condense pipes should be taken into one main pipe and carried to the drain, or tank underground in cases where the hot water can be used for any purpose, the water is not quite pure, but sufficiently so when not required for any delicate process of manufacture.

The supply of steam to the engine passes through a starting valve, the quantity admitted to the cylinder being regulated by the Governor and Throttle valve. The starting valve may be full open when the engine is at work; the speed should

be entirely regulated by the governor; the speed of the governor should be carefully adjusted, and all its parts kept very clean and in perfect working order, when this has careful attention, the engine will always run at a uniform speed, no matter what load or work is on at any time; if any machine is suddenly thrown out of action the governor should at once control the speed of the engine by cutting off the supply of steam.

We now come to the various classes of engines in general use, the leading features of each will be described; sufficient detail will be given to enable the reader to form a fair idea of each particular class, and thus help him to determine the kind best suited for his particular purpose.

## Oscillating Engines.

For mills or factories requiring small power, and where the floor space is limited, these are a useful class of engine. They are simple in construction, and are not very liable to get out of order; the moving parts are few, and comparatively inexperienced men can look after them. They are made both in the vertical and horizontal forms, and in some cases with the steam cylinders inclined at an angle of about 60°, when made in this way, they are usually con-

structed with double cylinders with one crank-shaft and fly-wheel. They are sometimes made in the form of wall engines; all the parts are fixed to a strong plate, which is bolted direct to the walls of the building; in this latter case the framing should be made very strong, and be very securely bolted to the walls. As a rule, these engines are not used in larger sizes than 8 horse-power nominal, the horizontal form is most generally preferred. It should be made with a double crank, with the main bearings on each side of the bed-plate; it will thus be self-contained and be independent of the walls. The steam and exhaust pipes should be attached to gun-metal trunnion pipes, provision being made for lubrication at the glands through which the steam and exhaust pipes on either side of the engine pass. The slide-valves may be worked by a link motion, this allows the engine to run in either direction; the steam cannot be used expansively. All parts of the engine should be well balanced, the stuffing-box made long, the piston and slide rods of steel, the main bearings of gun-metal and made wide. Lubricators should be provided at all moving parts, and for lubricating the interior of the cylinder, a lubricator may be fixed on the *inlet* steam pipe, the oil passes in with the steam. The "Porter" governor is the

most suitable; it is very sensitive, and not liable to get out of order. Feed-pumps for supplying water to the boiler should *not* be attached to the engine in any case, separate feed apparatus should be provided in the boiler house. Engines of this class should be worked with steam of a pressure of at least 50 lbs. per square inch, and be run at a piston speed of about 300 to 400 feet per minute. There is a great advantage in using double-cylinder engines, because the cranks are set at right angles, and thus allow the engine to be started at *any point of the stroke.* They also run more easily and regularly, and with less friction, all parts being in balance the strains are more equally divided.

In starting these engines, the condense water should first be run off the steam pipe by opening the cock *above* the starting valve; the steam should then be let into the cylinders to warm them, the condense cocks at the top and bottom cylinder covers being opened, then gradually open the steam valve and give full supply, and leave the throttle-valve to regulate the quantity of steam admitted to the cylinder according to the work to be done. Be sure that the lubricators are well charged with oil, and in good working order, the pipes should be examined each day before starting, to ensure that the passage

for oil is clear; in some cases the holes get stopped with dirt, and the oil is prevented from reaching the bearings. When the engine is stopped for the day, drain the pipes and cylinders, and get as much of the condense water away as possible. The object should be to leave all the parts of the interior of the engine and pipes quite free of water, and as dry as possible.

## VERTICAL ENGINES.

These are made as "High-pressure," or "Non-condensing," "Condensing," and "Compound," and each of these types is made in several different forms, although the principal of working does not differ.

The high-pressure kind, which are mostly used, are made in three principal types, viz. "Table," "Side or A frame," and "Inverted cylinder engines." The first named have the cylinder fixed upon a low table, the piston-rod is keyed to a cross-head above the cylinder, to which are attached the two side rods; these are connected *below* the table, and have a short rod keyed on at the centre, this has a strap end and brasses, and works upon the crank-pin. The crank-shaft is placed near the level of the base-plate, and runs in bearings cast upon it, the end or back bearing is in the wall of the house, the fly-

wheel being next the wall. This kind of engine is suitable where the floor space is small, and when it is necessary or desirable to have the crank-shaft *close to the floor*. The engines should not be worked at a piston speed exceeding 250 feet per minute, and a steam pressure may be used of from 35 lbs. to 50 lbs. per square inch. The wear of this kind of engine is very small, they are simple in action, work very evenly and steadily, and are not liable to get out of order.

*Side-frame Engines* are made with a side or hollow box frame resting upon a bed-plate, the cylinder is placed on the bed-plate in front of the frame, the crank-shaft runs in bearings cast on the top of the frame. This engine is suitable when it is desired to keep the fly-wheel and crank-shaft *above* the floor, they also have the advantage of being independent of the walls, and as they are self-contained, the driving pulley can be placed *outside* the fly-wheel; this allows greater facility for putting on the driving belt. The frame should be very substantial, and be well spread at the feet to ensure a firm seating on the bed-plate. These engines can be run at very low speed, with a small pressure of steam, and are very suitable for tem-

porary use in case of a break-down; they do not want much skill in fixing, and can be rapidly laid down ready for work. When used for temporary purposes, they may be bolted direct to a frame of timber, the latter being well secured to the ground.

*Inverted Cylinder Engines.*—These are made in the same way as the last, except that the cylinder is fixed on the top of the box frame and *inverted*, and the crank-shaft is placed near the bed-plate level, with one end working in a bearing cast on the bed-plate, and the other in a wall-box in the wall of the engine house. The fly-wheel is keyed on near the wall, and the driving pulley between it and the bed-plate. In some cases the crank is made double, and runs in two bearings cast on the bed-plate; the engines are in this case self-contained, and are more convenient for fixing quickly and removal when done with.

This kind of engine is not usually to be recommended; as the packings give some trouble, and in many other respects they are not a very desirable class of engine. They are seldom made in larger size in this form than 10 to 12 horse-power nominal.

*The side-frame engines* are sometimes made as condensing engines; in this case an entablature instead

of a side frame is the most convenient form, the air-pump and cold-water pump being worked off the crank-shaft between the columns or inside the frames; if this cannot be done, the air-pump may be worked on the other side of the entablature, and the condenser placed near, or it may be worked direct off the piston-rod, and fixed *under* the steam cylinder. There are several modifications of this kind of engine; it is advisable, however, not to use any engine complicated in any of its parts, or where all the parts cannot readily be got at for examination and repairs.

There are many other modifications of Vertical engines, but as they are seldom used they do not need any detailed notice.

## Horizontal High-pressure, or Non-condensing Engines.

This form of engine is the most useful kind, and is to be recommended in preference to other types, except in cases where the floor space is limited, when a vertical engine should be used. Horizontal engines being so well known, much description in detail does not seem needful. For sizes above 8 horse-power nominal an expansion slide should be provided,

with variable adjustable gear. All the rubbing or bearing surfaces should be large; it must be borne in mind that *friction is not increased* by extending the surfaces. The best form of guides are those cast on the bed-plate on each side, with sliding guide-blocks working between raised edges to retain the oil. The piston and slide rods, also the cross-head and crank-pin, should be steel. The stuffing-box of the piston-rod should be long, and when the size of the cylinder exceeds 16 inches diameter, a stuffing-box at the back cover should also be provided. A crank disc, balanced at the back, is preferable in most cases to a crank. The fly-wheel should always be bored out at the boss, and fitted with two keys, in sunk beds in the crank-shaft; the rim of the wheel should be turned and carefully balanced; the boss should be cast split, and after it is bored out it should have wrought-iron hoops shrunk on each side. Condense cocks and pipes should be fitted at each end of the cylinder, as before described. The cylinder should be provided with a grease cock to lubricate the inside, and provision should be made in the covers for indicating the work done by engine when required. The cylinder should be bolted to the bed-plate by four or six turned bolts, according to the power of the engine, it should rest on planed

surfaces, and be fitted between joggles cast on the bed-plate. All moving parts should be provided with check nuts, and in some cases they should also be cross-pinned to prevent any part from working loose. The governor should be Porter's patent high speed, careful attention should be given to perfect adjustment of the speed, also to all the levers and joints, to ensure that it works without any undue friction.

These engines may be run at a speed of 300 to 400 feet per minute, and the steam may be used from 50 to 60 lbs. per square inch. Observe the same rules as the last in starting and stopping the engine.

*Horizontal Condensing Engines.*—The most usual form of these engines is for the air-pump and condenser to be fixed at the back of the steam cylinder, and worked direct off the piston-rod at the back cover. The condenser in this case usually surrounds the pump. The cold-water and circulating pump is worked off the cross-head of the engine. Variable expansion slide-gear is provided. All the fixed parts of the engine should be attached to one cast-iron bed-plate. The manner of working these engines, being so well known, need not be described. Engines of this class can only be used

with advantage where there is a plentiful and cheap supply of water for the purposes of condensation, they are economical in action, and effect a saving in fuel above the non-condensing engines just described. The piston speed should not exceed 200 to 220 feet per minute, the pressure of steam may be 40 to 50 lbs. per square inch. Expansion slides should be fitted to the engine; the cut-off will be regulated by the work, it is usually cut off at a quarter to two-thirds of the stroke of the piston.

*Compound Horizontal Engines.*—These are a favourite form of engine, and are less costly in the first instance than the beam kind, they are usually arranged with the high-pressure cylinder in front, the low-pressure cylinder behind, and the air-pump and condenser beyond this. They of necessity take more floor space, and can only be used where there is sufficient room; they are more simple in construction than beam engines, and having fewer moving parts, are less liable to get out of order.

Engines of this class are also made coupled, with the high-pressure cylinder on one bed-plate and the low-pressure cylinder on the other, with one crank-shaft and fly-wheel; the air-pump in this case is worked at the back of the low-pressure cylinder,

and the cold-water and circulating pump at the back of the other; one governor controls the two engines. These engines give the highest results in working, and are very economical as to the fuel consumed in the boilers. There are many forms of compound horizontal engines, but the main features and system of construction do not much differ.

The particular circumstances of the case must decide the best form of engine for the purpose. As a general rule compound engines are not suitable for rapid working or where the load is very irregular. They give the highest results when pumping water, blowing air for blast-furnaces, and for ventilation of mines, or doing ordinary steady mill work.

## Beam Engines.

*High-pressure Beam Engines.*—These engines are still preferred by some people, and are very efficient in working, their form does not vary much. The beams may be made of wrought or cast iron, and with single or double cheeks. The connecting rods should be wrought iron, the piston and slide rods of steel as before. All the fixed parts should

be attached to a strong bed-plate resting on a good foundation of brick and stone work. The cylinder should be provided with variable expansion slide-gear.

All the parts of this class of engine are in perfect balance, it is specially suitable for pumping water and in cases where the work to be performed is regular. The pressure of steam used should be about 45 to 50 lbs. per square inch, and the piston speed about 220 to 250 feet per minute. In starting these engines, especially when of large size, first drain all the condense water away from the pipes and cylinders, then slowly open the starting valve, to well warm the cylinders with steam, and to allow the parts to expand slowly by the heat. All parts of the engine should be well lubricated, the joints of the parallel motion will require particular attention. For starting the engine when on the dead centres, a rack, plate, and bar should be provided, or a ratchet or rack may be cast on the rim of the fly-wheel, and a lever working on a fixed fulcrum may be used. The back bearing in the wall should have a pipe carried to the front of the wall, to allow of easy lubrication. Be very careful as to the condition of the lubricators and grease cups, that they are kept clean, well filled with oil, and in perfect working

order. The bright parts of the engine should be cleaned *before starting each day*, and all the nuts and pins tried, to make sure they are in good order, and that nothing is loose.

*Condensing Beam Engines.*—These are constructed in the same way as the high-pressure described at p. 57, except that an air-pump is worked off the beam about midway between the main centre and the connecting rod, the pump is usually half the stroke of the cylinder; the condenser is generally placed at the side, and the hot well on top of the air-pump. The cold-water pump to supply the condenser is worked off the beam also. The pressure of steam should be about 40 to 50 lbs. per square inch, and the piston speed about 220 feet per minute. A good supply of clean water free from deposit and at a cheap rate is essential to these engines, otherwise the cost of working will exceed non-condensing engines.

*High and Low Pressure Beam Compound Engines.*—These engines are made in much the same way as the last described, except that they have two cylinders, one for high pressure and one low pressure, the steam passes first into the high-pressure cylinder,

and then exhausts into the low-pressure cylinder, from which it is discharged to the condenser, the cylinders are generally worked close together at one end of the beam. These engines are only suitable for large sizes, they are very economical in working, and are specially adapted for driving mills and pumping water for towns, or pumping sewage. They are sometimes coupled, the high-pressure cylinder being worked by one beam, and the low-pressure cylinder by the other, with *one* crank-shaft and fly-wheel; this is placed between the two engines, in this case the steam passes into an intermediate receiver, the cold-water and circulating pumps are worked by one beam and the air-pump by the other. Engines of this class are specially suitable for pumping water, and are very efficient in action, in cases of this kind they work slowly and steadily, the work as a rule is constant, and on this account there are no sudden shocks to the engine; they are peculiarly adapted for waterworks purposes. The consumption of coals at some of the London waterworks where this type is used is not more than two pounds per indicated horse-power per hour.

When these engines are used for pumping, the pumps are usually placed at the crank end of the

beam, they are made double-acting, and on the ram and piston plan, the valve-boxes are below the bed-plate; bonnets are provided at the suction and delivery valves to allow easy and rapid examination. The rules to be observed in working these engines, mentioned hereafter, do not much differ from the last type, only competent men who have special experience should be employed to attend to them. The first cost of this kind of engine is much more than those previously described, but when well looked after, the economy effected in the consumption of coals by their use well pays the extra outay.

### Working the above Engines.

The same rules will apply to most kinds of condensing engines. Before starting, the cylinders should be warmed and cleared of condensed water by opening the cocks at the bottom of the steam and exhaust pipes, also the cocks at each end of the cylinder. The grade of the expansion slide should be set according to the work to be done, if this does not vary much from day to day it need not be touched when once set. See that the lubricators are well filled with oil, the cottons in good order, and the holes clear of dirt. The main slide of the engine should be worked to

and fro by the hand-lever on the weight-shaft, the eccentric rod being thrown out of gear by means of the gab end; the cylinder at each side of the piston is thus thoroughly warmed by the admission of steam, it also enables all parts to expand slowly, and so prevents the starting of any of the joints. See that the injection water (in the case of condensing engines) is ready, and then slowly open the starting valve to its full extent, observe the vacuum gauge and adjust the injection water. When the cylinder is jacketed, admit steam into the jacket at the time of warming up, the condense water from the jacket should drain back to the boilers. When in good working order the vacuum made in the condenser should be 27 inches. The consumption of fuel should be about 3 to 4 lbs. per indicated horse-power per hour, this consumption only applies to engines of the highest class of manufacture.

All the gun-metal bearings, caps, and keys of the moving parts should be examined each day before starting; make sure that all parts are bearing fairly, also that they are getting free and sufficient lubrication. Test the level of the crank-shaft at certain periods by placing a spirit level on top of the shaft, this will show the condition of the back bearing; if any part of the engine runs hot it is a

sign of undue friction in some part, and should have immediate attention. The engine should be indicated on certain occasions to test the actual work it is doing, as, however, this operation requires much care, it can only be done by experienced people.

The piston should be drawn at least once each six months, and the air-pump bucket, and valves examined, the cylinder slides should also be looked to, and adjusted if necessary. The connecting rod bearings should be examined and closed up if slack. The main bearing brasses in all well-made engines of any size should be adjustable so as to take up the wear in any direction and maintain the exact level and position of the crank-shaft. The back bearing of the crank-shaft in the wall should be easy of access, not only for lubrication, but for examination and adjustment of the gun-metal bearings.

*The oil* used should be of the mineral kind. Lard or other animal or vegetable oils are not suitable for lubrication, as they coat or gum up the bearings and make the moving parts run heavily. Tallow, unless it is of the very best quality, should not as a rule be used, as some of the fats contain acid and are injurious to the interior of the cylinder, piston and slides, &c. The stuffing-box packings

must have the most careful attention, common hemp packing is about the best kind to use, the glands should be fitted, whenever possible, with three studs, to ensure an equal amount of pressure being put on the packings all round, and also that no undue friction is placed on any part of the rods passing through the packings and glands; no leakage of steam should be permitted at the glands. The oil from the piston and other rods should be caught in shallow copper trays, the refuse should be used for other purposes, but *not* for lubricating the engine again, only perfectly clean oil should be used.

The engine should be painted, and twice varnished when laid down; when this is well done it will last for years, and can be easily kept clean by wiping down each day; the varnish prevents the oil from sinking into the grain of the iron, a coat of varnish once in every two or three years will keep the engine in good order.

Condensing engines require more skilful and careful attention than high-pressure or non-condensing engines, the moving parts are more numerous, and the operations of the engine require more personal attention. The driver should carefully watch the steam and vacuum gauges, in order to

detect any defect in any of the working parts. The engine should be well oiled at each stopping time, and all parts kept perfectly clean.

### CORNISH AND DIRECT-ACTING ENGINES.

These are principally used for pumping water, and are somewhat of a complicated nature, they are very economical in action, especially as to the consumption of fuel; they are, however, only suitable for large powers and for special circumstances. As they are not adapted for mill or manufacturing purposes no description will be given. Any one desiring any detailed information as to these and other kinds of engines is referred to the author's books upon 'Pumps and Pumping' and 'Steam Boilers and Engines.' *

* 'Pumps and Pumping,' by F. Colyer, M.I.C.E.; 'Steam Boilers and Engines.' London: E. & F. N. Spon.

## CHAPTER VII.

### FOUNDATIONS OF ENGINES AND ENGINE HOUSES

#### FOUNDATIONS.

*The foundation of an engine* requires the most careful consideration, a good bottom must first be obtained, the depth of the foundation and the excavation under ground will, of course, depend upon the power and class of the engine. On the bottom a bed of concrete should be laid from 18 inches to 24 inches thick, and on this a brickwork foundation built with Portland cement, the footings should be two courses (6 inches thick) and four courses or 24 inches deep. A Portland or Yorkshire stone, about 18 to 24 inches thick, should be laid on top of the brickwork, made perfectly level and bedded in cement; the bed-plate of the engine is then to be firmly bolted down by long bolts, passing some depth into the brickwork; when the engine bed is levelled and bolted up the bolts should be run up with Portland cement grout. The stone should be squared,

tooled, rubbed on the top and on all sides, and "hacked" to a fair, even, and level bed on the lower side; the top must be made perfectly level, and before the bed-plate of the engine is put down it must be tooled to a perfect surface, *dead* level. The lower part of the engine bed-plate should be planed to ensure it having an even bed on the stone. Pockets for the cottars or keys of the holding bolts should be left in the brickwork, the cottars should bear upon cast-iron plates, and these on stones 6 to 9 inches thick, built across the foundation. In marshy districts piles should be driven to the firm ground, and a platform of timber made on top of them, on this concrete should be laid. Skilled advice should always be obtained for the foundations of engines and machinery, as it must be borne in mind that upon the firm and unyielding foundation will depend the accurate working of the engine, and the consequent reduction of wear, and cost of repairs; a good solid foundation is a good investment for the future. After the bed-plate of the engine has been made perfectly level, and the bolts run up with cement grout, the work should stand for at least two weeks to allow the brick and stone work to dry, otherwise the working of the engine may do permanent injury to it before it has

had time to set. It must be borne in mind that cement work increases in strength by time, and if the joints are disturbed or broken before they are set, the work is destroyed. The foundations for the larger kind of beam engines are not such a simple matter as that described above, arrangements have usually to be made under the floor line for the air-pump, condenser, and in the case of pumping engines also for the pumps and valve-boxes, as well as the pipes. When the engines are of large power the foundation stone should be granite, it is much more expensive, but well repays the outlay after the lapse of years, in these cases the granite stone is usually only placed under the cylinder, the main column, the crank bearings, and any other parts that have a direct bearing on the foundation.

## Engine Houses.

The construction of these will depend upon the class of engine, and the purposes for which they are to be used, for engines of ordinary size the walls of the house should be 14 inches thick, and the height from the floor line to the wall-plate about 12 feet. The roof may be constructed with wood or iron trusses, close boarded and covered

with slates. The walls may either be whitewashed or plastered and painted, the latter plan is the best, it is cleaner and more economical in the end. The floor may either be wood, stone, or Stuart's granolithic paving, the level should be at least 12 inches above the outside ground line, to keep the place dry. The windows should be a good size, and afford plenty of light and ventilation when required; the door may be half glass. The dimensions of the house will depend upon the size of the engines, when duplicate engines are provided a space of at least 6 feet to 8 feet should be left between each. The minimum space between the stone bed and the walls of the house should not be less than 4 feet, this gives room for the fly-wheel and driving pulley.

*Channels for Pipes.*—If there are any pipes under the floor line, brickwork channels should be built to receive them; the side walls should be 9 inches thick, the bottom paved with stone or it may be concrete cemented on the top, it should be laid to a fall to keep it clear of water. The width between the walls should not be less than 14 inches, this will much depend upon the size of the pipes, ample room must be allowed to remake the joints when necessary. The top should be covered by loose cast iron

plates let in flush with the top of the floor, a rebate being made in the floor (if stone) to receive them; or 1½-inch L iron will do very well when the floor is of wood or granolithic cement paving; the floor covering is stopped at the L iron, and the plates when shifted do not wear away the edges of the boards or other covering.

### Fittings for the Room.

Vacuum and steam gauges should be fixed on the walls at a spot where the man attending the engine can easily read them. A set of spanners should also be placed in a rack on the wall, a sufficient number should be supplied to take every size of nut; key and socket spanners should also be provided. These spanners *should not on any account be allowed to be removed from the engine house*, as in case of a sudden emergency they might be out of the house or mislaid, and an accident or stoppage caused, which might be of serious consequences, and entail heavy loss.

*The Oil-cans* should be kept on a copper tray, two or three different sizes and descriptions of cans should be provided to enable the driver to safely and conveniently reach all parts of the engine.

*An "Engine Counter"* should be provided to record the number of revolutions made by the engine, and in the case of pumping engines the quantity of water pumped, and the "head" or pressure of the water should also be recorded. In some cases a continuous record is kept by an apparatus having a cylinder to which a roll of paper is attached, this is worked by a clock, it shows the work done at any particular hour, and also the work from day to day. The cylinder and roll of paper are locked up and cannot be tampered with by the engine driver; this plan is useful as it gives a permanent record of the work done.

*A Cupboard* should be provided for the driver to keep his tools, wipings, and other materials in; he should have a chisel, hammer, a few files, a shifting spanner, and a pinch-bar. Spare oil and cotton waste may also be kept here.

*Bells, Electric or Pneumatic*, should be fixed on the walls of the engine house, with a series of dials or indicators communicating to various parts of the mill, &c. A message can be sent from any part telling the driver to start, stop, or run easy; this plan is much preferable to common bells or gongs worked by a code of signals, according to the number of strokes, as

mistakes may arise by this system. The electric or pneumatic system above recommended is specially desirable because the man can *see* the message, and can then be in no doubt as to the order intended to be conveyed; the author has used the system for some time, and can confidently recommend it for perfect working.

*Rules for working* should be printed, framed, and placed upon the walls of the engine house in a conspicuous position; these should instruct the driver what his duties are and also what he is to do in case of emergency. The rules should be in clear and concise anguage, so as not to leave the man any excuse for not understanding and rigidly obeying them. By strict observance of proper rules, accidents may be prevented, and also undue wear of the machinery and gear. The author believes that many of the accidents to machinery that take place might be prevented by a more perfect system of working as far as the men are concerned.

*Cleanliness* and a trim appearance both in the room and the machinery should be insisted on; it will be found that men take a pride in the machinery when this is carefully attended to, with the result that the wear is much less, and the chances of a break-

down are very much reduced. The engine room of a mill should be the show place of the establishment, and the perfection of cleanliness and order.

*Strangers* should not on any account be allowed in the engine or boiler houses unless by special permission, and no one except those in charge should on any pretence be permitted to interfere with the machinery.

*Engine Drivers.*—A system of rewards to the men for the trim and good condition of the machinery will induce them to keep all in perfect working order, a careless man should on no account be entrusted with an engine of any kind. It need hardly be said, that in the case of large engines, serious loss may take place, and possible injury to human life, by the carelessness or neglect of the driver. A man who is personally clean will, as a rule, keep his room and machinery in the best condition, and be orderly and systematic in all that he does. Long spells of duty should be avoided whenever possible, as from natural fatigue and the enervating air of the room the men are sometimes so tired they cannot well perform their duties in a proper manner.

The class of man employed to drive Engines will depend upon their power and description, com-

pound and large Beam engines of all kinds, as a rule, require the services of an experienced man, not only conversant with driving the engine, but one who has a leading knowledge of the details of the various parts. Such men will sooner discover any radical defect in the engine, and by taking proper precautions in time may save a serious break down and consequent stoppage to the machinery. This is a matter of great moment in most mills and manufactories, as much loss of time and labour may be caused by such stoppage. A well-paid man is generally a good servant, and one likely to care for the machines under him.

Most of the necessary working details of engines and boilers have been touched upon, except for cases of a very technical nature, and which are beyond the province of this work. In the author's book upon 'Steam Boilers and Engines' (E. & F. N. Spon) will be found details of all the best forms of engines and boilers; their construction is fully treated, also the working data and the results of performances are given; to this book all readers desiring more detailed information as to the construction of such machinery are referred.

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